THERMODYNAMIC LAWS: NEW PARADIGM TO UNDERSTAND GLOBAL WARMING

Jorge Nowell-Enriquez

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Abstract

For many years, attempts have been made to understand global warming and climate change. While I've identified several uncertainties in the CO2 and greenhouse gas (GHG) albedo theory, I don't intend to dismiss their connection to global warming. However, we must recognize that correlation doesn't always imply causation. The CO2 and GHG albedo theory, based on theoretical light properties, offers a limited understanding of planetary heating. Thermodynamic laws provide a more comprehensive framework. To protect Earth's remarkable biological system, a paradigm shift is needed. This new paradigm, characterized by its simplicity and clarity, addresses the vulnerabilities of the albedo theory.

Most importantly, it empowers individuals to understand how their actions contribute to climate change. This is a call for collective and personal transformation before Earth's cooling system reaches its threshold, leading to irreversible heating. This is an invitation to research and evaluate global warming within the scope of thermodynamic laws.

Introduction

The scientific discussion surrounding CO2, GHGs, and climate change is ongoing and multifaceted. Acknowledging the optical limitations of these gasses is crucial, but it's only one piece of the puzzle. Continued research, consideration of all contributing factors, and a commitment to evidence-based understanding is essential in navigating this complex issue. This proposal has a goal to raise questions and considerations regarding the role of CO2 in global warming. While not dismissing its influence, it seeks to incorporate thermodynamic laws (Thermodynamics, 2024)and address potential incongruencies related to UV, IR, and atmospheric interactions.

This proposal highlights several doubts about the complexities of CO2-atmospheric interactions and the need for ongoing research. While some arguments require further investigation and nuanced context, these do not dismiss CO2's influence in global warming. This proposal has not as objective to dismiss CO2 influence in global warming, but the aim is to improve the theory adding to the global warming

equation thermodynamic laws, however, several questions remain about the role of CO2. A comprehensive understanding of all contributing factors, including CO2's role alongside other greenhouse gasses and thermodynamic principles, is crucial for addressing the multifaceted challenge of climate change. A change of paradigm is important to solve the constantly failing projections about climate change with the increasing catastrophic consequences producing great loss and threatening the mere existence of life.

This work describes how thermodynamic laws are a better tool to understand global warming using the entropy of carbon oxidation to explain global warming besides questioning the behavior of UV and IR light absorption by carbon dioxide in a freezing environment, including the question if does a freezing atmosphere at-55 C cool heated CO2? (*Conduction Heat Transfer*, 2022)

Important is the description of how polar ice is cooling warm oceans that absorb almost all waste heat (90%) produced by human activity and melting by exchange of heat. This work allows us to visualize a catastrophic climate without marine currents once the cryosphere disappears, transforming the weather systems. Finally, the objective of this paper is promoting the discussion for better adaption-mitigating strategies, facing a catastrophic mass extinction.

The new paradigm

A New Paradigm for Climate Change: Beyond CO2 albedo

This new paradigm on climate change proposes a shift in focus, embracing thermodynamic laws to argue that residual energy (waste heat) released into the environment is the primary driver of warming (Bendig et al., 2013). While CO2 plays a role, it is viewed as a sub product of processes that cause global heat imbalance.

As will be explained, the albedo theory, which focuses on light reflection, falls short as a complete explanation for global warming. Instead, the emphasis is on the exothermic reactions like fossil fuel combustion, where the oxidation of

carbon and hydrocarbons releases vast amounts of waste energy directly into the environment, heating it significantly (Combustion Heat, 2024*)*.

It's important to acknowledge that some heat is crucial for life. Up to a certain point, it fuels biological processes like photosynthesis, allowing plants to convert CO2 into carbohydrates and stimulating growth, much like the seasonal cycles of spring and summer. However, this "Goldilocks zone" is crucial: excessive heat beyond this threshold becomes detrimental, inhibiting growth, reproduction, and ultimately jeopardizing all living creatures, a threat to human existence. Each species has its own temperature tolerance for optimal thriving (Lenton et al., 2023).

The most critical realization is that numerous activities beyond CO2 emissions contribute to this free heat, Forman et al. evaluated in 2005 the global waste heat potential collectively tipping the planet's energy balance (Forman et al., 2016. Industrial processes, forest fires, and some agricultural practices all play a role.

This new paradigm, by focusing on the broader concept of residual energy and its various sources, as explained by Building Energy Research Center of Tsinghua University, offers a more comprehensive understanding of climate change (“Industrial Heating and Residual Heat Emission,” 2024). It encourages us to look beyond isolated solutions like carbon capture and sequestration, and instead consider a wider range of actions to address the diverse sources of excess heat plaguing our planet.

Residual Energy – Waste Energy

Understanding Residual Energy and its Role in Climate Change.

(*Waste Heat - Energy Education*, 2024)

Energy, the engine of everything, can be a fickle beast. While often desired, its unused form – waste energy – lingers like an unwanted guest, impacting our planet's delicate temperature balance because it is given as thermal energy to the environment (Energy Education, 2024). The evaluation of Foreman et al. (Forman et al., 2016)shows that global waste of

energy as heat in 2012 was 70% of the total consumption. According to the laws of thermodynamics, this leftover energy simply exists, neither being created nor destroyed (*1st Law of Thermodynamics*, 2024).

To illustrate its role in global warming, let's turn to the popular vehicle (NASA, 2024). Its gasoline-powered engine extracts only between 10 and 30% of the fuel's energy for movement (U.S. Department of Energy, 2024b). The rest? A whopping 70% transforms into heat, released by the engine itself and diligently dispersed by the cooling system (Caton, 2018; Heat Rejection, 2024). So, for every liter of gasoline burned, nearly three-quarters of the energy turns into the environment as heat (Carnot Cycle, 2021).

Certainly, CO2 released during combustion plays a part, but it's not the sole culprit. This wasted heat, the direct consequence of energy inefficiency, contributes significantly to the problem. One car might seem insignificant, but consider the International Energy Agency's estimation of nearly 100 million barrels of oil consumed daily worldwide. And oil isn't the only offender, even clean energy sources used by electric motors like electric trains generate heat, albeit less, that ultimately finds its way into the environment. An example of this heat are New York City subway stations in summer (engineeringtoolbox, 2024).

The air conditioner, our savior in sweltering summers, also turns into a double-edged sword. While it provides comfort, its reverse cycle function, used for heating, efficiently could pump residual heat back into the room. Alvarez-Quintana explains that vapor-compression refrigeration systems put “a lot of residual thermal energy into the environmet,” (Alvarez-Quintana, 2023). Ironically, the very mechanism seeking to cool contributes to rising temperatures.

These scenarios highlight the importance of understanding residual -waste- energy not just as a scientific concept, but as a significant factor in climate change. We must address not only pollution emissions, but also energy usage and its inherent inefficiencies as the waste heat produced by server farms or data centers described by Ben Raker (Ben Raker, 2024)and as the solutions proposed by Equinix (energy-efficiency-centre-of-excellence-ebook, 2021). Embracing

cleaner technologies and optimizing energy use are crucial steps toward mitigating this often-overlooked contributor to a warming planet.

How is CO 2 Related to Global Warming?

The Carbon Connection. Unraveling CO2's Role in Global Warming

The link between carbon dioxide (CO2) and global warming remains one of the most pressing scientific debates of our time. While a complex issue with numerous contributing factors, understanding CO2's role heating is crucial to understand the rise in Earth's temperature.

Atmospheric CO2 concentration is a prominent indicator of fossil fuel usage and carbon combustion. When we burn fossil fuels like coal, oil, and natural gas oxidation takes place. This process essentially combines carbon from the fuel with oxygen in the air, generating both CO and CO2 gasses.

Crucially, these oxidation reactions are exothermic, meaning they release energy in the form of heat. For instance, producing one mole of CO releases about 25 kilocalories (kcal) of heat, while forming one mole of CO2 delivers a significantly higher, 90 kcal. The enthalpy of formation of CO is -113 kJ/mol (Argonne National Lab., 2024), and the for carbon dioxide enthalpy of formation is -393.472 kJ/mol (anl.gov). This substantial energy release is precisely why fossil fuels have been such convenient and widely used energy sources throughout the industrial era.
Nevertheless, CO2's significant heat released during combustion is a key driver of global warming, demanding serious attention and action. Every day the consumption of oil energy is equivalent to 146,220 kilotons of TNT (equivalent to 9748 “Little Boy," the atomic bomb dropped on Hiroshima of 15 kilotons, 63 TJ) (softusvista, 2024). Exercise:
The daily global consumption of coal is 23,055.555 tons (8.3 bt/yr) (IEA – International Energy Agency, 2023)
The energy of "Little Boy" was 15 TNT kilotons. If a kiloton is 142.7 tons of coal,
to how many *Little Boy’s* equals the energy of the carbon consumed every day?

Andrew King and Steven Sherwood, climate scientists, calculated that 380 zettajoules of energy had been released between 1971 and 2020. This energy is equivalent to around 25 billion times the energy released during the detonation of "Little Boy," the Hiroshima atomic bomb, 90% absorbed by the ocean (Harry Baker, 2023). The heat absorbed by oceans, since 1877, according to the reconstruction of Zana et al. is equivalent to 436 x 10^{21} J, and between 1971 and 2010 the oceans absorbed 290 JZ (1 JZ = 10^{21} J), heat produced by human activities (Zanna et al., 2019).

Understanding the intricate link between CO2, fossil fuel usage, and global warming is critical in addressing the challenge of climate change. By acknowledging CO2's exothermic properties and its substantial contribution to global warming, we can pave the way for informed solutions and sustainable practices for a healthier planet.

How the Earth is Cooling

The Cooling Paradox: A Delicate Balance Under Threat

While the idea of a warming planet dominates climate change concerns, a less-discussed phenomenon deserves attention: the potential consequences of melting polar ice and the Atlantic and Abyssal oceanic currents lowering speed.

Human activities generate vast amounts of waste energy released as heat mostly into the hydrosphere using water as coolant. This heat follows a complex path, some reaches the upper atmosphere, while the majority (90%) gets absorbed by our heating planet's vast oceans reaching temperature records as reported by Copernicus' OSR7 (EU Copernicus, 2023)

The oceans play a crucial role in climate regulation. Acting as a giant thermal reservoir, they absorb almost ninety percent of the global heat, including what humans generate (NASA's Jet Propulsion Laboratory, 2022). This heated water then circulates, flowing towards the Arctic and Antarctic regions regulating global climate systems; the actual slowing down of the oceanic currents (EU Copernicus, 2023)(AMOC) will produce unimaginable climate changes (National Ocean Service, 2024). The same warming and slowing down effect was observed by Li et al. on the Abyssal ocean circulation (Q. Li et al.,

2023).The hypothesis of Zanna et al. is that the heating of the ocean induces AMOC reduction and that ocean heating will have an important impact in global and regional climate changes and sea level rise (Zanna et al., 2019).

As warm water reaches the polar ice caps, it cools down through contact and surface melting. This process mirrors the familiar phenomenon of ice melting in a soda cup. The scale, however, is truly immense. Currently, Earth's polar ice has the capacity to absorb the heat generated by our daily consumption of approximately 100 million barrels of oil and 9 million tons of coal. Carrignton explains the heat absorbed by oceans is equivalent to the energy released by one nuclear bomb by second last 150 years (Carrington & editor, 2019).

As a fading buffer, this cooling mechanism, while effective, is not infinitely sustainable. The Earth's ice caps are finite resources, and their continued shrinkage poses a serious threat. Once they largely disappear, our natural heat sink will be significantly diminished, potentially leading to drastically higher global temperatures, exceeding mere increases of two or three degrees Celsius.

The melting ice isn't just a thermal regulator; it's also a critical habitat for various species. Extensive ice loss threatens ecosystems and biodiversity, contributing to global warming, mass extinctions and disrupting fragile food webs.

Understanding the complexities of Earth's cooling mechanisms and their interplay with human activity is vital. Preserving our polar ice caps is not just about mitigating future temperature spikes; it's about safeguarding vital ecosystems and ensuring the planet's long-term sustainability. Ignoring this delicate balance puts us at risk of irreversible damage and a cascade of unforeseen consequences.

Before than expected

2023: A Year of Unexpected Climate Extremes

(World Meteorological Organization (WMO), 2023)

2023 witnessed a record number of unexpected climate phenomena, leading to numerous catastrophes and exceeding many global warming-related records (National Oceanic and Atmospheric Administration, 2024). Human activity's role in climate change is undeniable. This year highlighted how quickly predictions can be surpassed, showcasing the limitations of current models. Several factors contribute to misleading projections, including limitations of Global Climate Models (GCMs). This paper aims to advocate for a paradigm shift in understanding global warming and climate change, incorporating fundamental thermodynamic laws.

Extreme Events of 2023:

1. Unprecedented Heatwaves: Extreme heat waves fueled devastating wildfires across the globe.

2. Historic Rainfall and Flash Floods: Heavy rains triggered flash floods, particularly in areas like Vermont and New York.

3. Severe Storms: Intense storms battered the West Coast, with hurricanes and heavy rains causing widespread damage.

4. Atmospheric Rivers: California faced the brunt of atmospheric rivers, leading to significant flooding.

5. Rare Events: 2023 saw an increase in extreme and rare weather events, including wildfires in Hawaii and Louisiana, Canada's extensive wildfire season, and smoke-filled skies across North America.

6. Record Temperatures: 2023 was Earth's hottest year on record, with extreme heat waves in North America, Europe, and China. The temperature of sea water also reached a record.

7. Increased Heat Wave Intensity and Duration: Deadly heat waves became more frequent, intense, and long-lasting.

8. Flooding in Pakistan: Pakistan experienced record-breaking floods.

9. Intensified Hurricanes and Tornadoes: Hurricanes and tornadoes exhibited increased intensity and frequency.

11. Tropical Cyclones in the Mediterranean: The Mediterranean region saw an increased number of tropical cyclones.

12. Heavy Rains and Storms in Libya: Libya experienced heavy rainfall and severe storms.

13. Monsoon and Typhoon Activity: Sothwester US had a reduced activity; but China saw thres thypons in just one week. The North Indian Ocean cyclone season was above-average and deadly season, central-south Arabian Sea had very severe and extremely Severe Cyclonic activity.

Scientists involved in climate research acknowledged the unusual climate behavior in 2023 (Wu, 2023, 2024). Gavin Schmidt from NASA stated, "It was a very strange year... The more you dig into it, the less clear it seems'' (Seth Borenstein, 2024). Klare, Professor emeritus at Hampshire College, warned about the brink of a collapse of civilization like ancient civilizations (Klare, 2023). The United Nations Environment Program noted that climate change predictions

materialized far sooner than anticipated (*Extreme Weather | WESR - Climate Change*, n.d.).

I like to describe a few extreme events that are occurring more often, developing faster and becoming more intense. In addition, how the IPCC reports have been questioned.

Energy Imbalance and Warming Acceleration:

James Hansen, a pioneer in climate science, warned Congress about the planet's energy imbalance (EEI) leading to unpredictable warming pathways (J. E. Hansen et al., 2023). He highlighted new global temperature records exceeding his previous model's projections. This raises concerns about the accuracy of current climate models in capturing accelerating warming trends.

Model Limitations and Misconceptions:

However, scientists like Daniel Swain and Michael Wehner from the University of California, Los Angeles, emphasize the limitations of relying solely on models (Teirstein, 2021). They argue that many models are primarily weather models, not designed to predict long-term climate shifts. In my opinion, it seems that focusing on understanding complex nonlinear weather systems will be more important than solely attributing failures to models' inability to predict extreme magnitudes. Pierrehumbert explains the difficulty in climate models to cover the spectral lines of the differeeent energetic fecuencies to calculate aggregate effects (Pierrehumbert, 2011, p. 239).

Evidence of Unexpectedly Rapid Warming:

Despite differing views on model limitations, numerous observations point towards faster-than-anticipated warming. Notably, in November 2023, Sam Burgess of the Copernicus Climate Change Service announced that, only for a day, global temperatures had already surpassed the 2°C projected for the future (Koumoundouros, 2024).

Record-Breaking Heatwaves and Impacts:

2023 witnessed record-breaking heatwaves, making it the hottest year in human history. These scorching temperatures claimed heat-related lives and were described as "mind-boggling" by NASA's Jet Propulsion Laboratory (Earth

Observatory, 2023). The Southwest United States bore the brunt of this relentless heat.

Human Influence on Extreme Events:

The World Weather Attribution initiative underscores the human contribution to extreme events like heat waves, unusual cold spells, droughts, and excessive rainfall (*Climate Change Fuelled Extreme Weather in 2023; Expect More Records in 2024 – World Weather Attribution*, 2023; *Extreme Heat in North America, Europe and China in July 2023 Made Much More Likely by Climate Change – World Weather Attribution*, 2023). While predicting the exact timing and intensity of these extremes remains challenging, their increasing frequency and unpredictability are becoming increasingly evident.

Tornadoes on the Move: Climate Change and Shifting Patterns

Overheating due to climate change is influencing tornado patterns, potentially causing them to stray beyond the traditional "tornado alley" that encompasses parts of the Midwest. Studies suggest areas like Alabama, Illinois, Tennessee, and Arkansas could witness an increased risk of these destructive storms (Milman, 2023). While the exact reasons for this shift are still being investigated, researchers believe it's likely a consequence of global warming. Some experts also anticipate that tornado intensity and frequency might rise as temperatures continue to climb.

Seasonality Shifts and Complex Interactions:

Another intriguing development is the apparent change in tornado seasonality. Traditionally, tornado outbreaks were primarily associated with spring and summer. However, recent years have seen an increase in winter tornadoes, adding another layer of complexity to predicting and preparing for these events (Ashley et al., 2023).

Unanswered Questions and Research Efforts:

The influence of climate change on tornadoes remains an active area of scientific inquiry. While evidence suggests a connection between warming temperatures and shifting tornado patterns, researchers are still grappling with numerous

unanswered questions. The new frequency, timing, location, and intensity trends require further investigation. Detecting and predicting tornado behavior is becoming increasingly challenging (Gensini & Brooks, 2018).

Quoted scientists are diligently working to address these critical questions, but finding definitive answers takes time and meticulous research. The complex interplay of various factors makes straightforward explanations elusive. Nevertheless, understanding how climate change impacts tornado behavior is crucial for improving early warning systems, implementing effective mitigation strategies, and protecting communities from the devastating effects of these storms.

Cryosphere in Flux: The Arctic's Melting Impact on Global Climate

The Arctic, warming twice as fast as the planet's average, triggers a chain reaction of changes in weather patterns with significant global implications. This rapid transformation, driven by a fast-changing cryosphere (Earth's frozen areas), presents unprecedented challenges. Data from NOAA's 2021 Arctic Report Card showcases a series of unusual events and complex alterations (Kiest, 2021).

The Arctic's Cooling Influence:

The North and South Poles act as Earth's "freezers," chilling ocean waters and influencing global climates. However, melting ice poses a major threat to this delicate balance (Jacobo, Julia, 2021).

Greenland's Accelerating Melt:

Greenlad’s melting exceeds previous predictions, as reported in the Proceedings of the National Academy of Sciences (Ciracì et al., 2023)melt. Scientists like Kaitlin A. Naughten highlights a faster-than-anticipated melting rate at the ice-ocean boundary (Naughten et al., 2023). These scientist alert Greenland is melted at accelerated rate

Antarctic Unraveling:

Naughten (Naughten et al., 2023)and colleagues raise an alarming concern: Antarctic ice melt is three times faster than historically observed, likely due to rapid ocean warming.

They argue that even aggressive greenhouse gas mitigation won't prevent ocean warming, emphasizing uncertainties in ice shelf melting projections. The British Atlantic Survey points that Thwaites fast and “irreversible” melting will have an important impact on sea level rise (British Atlantic Survey, 2023). This view finds support in studies by Lowry et al., who suggest Antarctic ice loss projections remain uncertain (Lowry et al., 2021). However, Pettit et al. think the collapse of Thwaites probably will happen in next five years producing an important increase of sea level rise (Pettit et al., 2021)

Misconceptions Debunked:

Skeptics once claimed Greenland was gaining ice. However, researchers like I. Velicogna (Velicogna, 2009), refuted this misconception, demonstrating not only sustained, but accelerating ice loss. Scientists alert Greenland is melting at an accelerated rate producing sea level rise (Rapid Ice Melting, 2021).

Sea Level Rise: A Pressing Threat:

The Arctic Report Card co-author Twila Moon warns of dire consequences. Melting ice and ongoing climate change will exacerbate coastal erosion, flood previously unaffected areas, and even increase inland flooding due to saltwater intrusion into groundwater tables (Jacobo, Julia, 2021)). Emma Robin describes how sea level rise will affect forty American cities as a consequence of arctic and glaciers melting (Emma Rubin, 2023).

Early Tipping Points:

Are Approaching Faster Than Expected?

The concept of climate tipping points, critical thresholds beyond which drastic and potentially irreversible changes can occur, has been gaining increasing attention. Although the Intergovernmental Panel on Climate Change reports (IPCC) define these points, recent research suggests some may be approaching sooner than anticipated. William Rippey and 11,000 scientists from around the world alerted that many

typing points have already been crossed and many others are almost crossed, resulting in a climate emergency (Ripple et al., 2021).

Tipping Points.

In a 2019 paper, Timothy Lenton and colleagues projected that nine tipping points, primarily within the cryosphere (Earth's frozen regions), could arrive earlier than expected (Lenton et al., 2019). In 2023 Lenton warned that tipping points are no longer linear projections, crossing one will produce domino effects and generate unmanageable systems (Studio, 2023). Additionally, research by Willcock et al. indicates several Earth systems are undergoing rapid shifts, potentially leading to system collapses sooner than previously thought (Willcock et al., 2023).

Global Warming Projections.

Stanford University's Noah Diffenbaugh and Colorado State University's Elizabeth Barnes employed artificial neural networks (AI) and historical temperature data to predict global warming (Diffenbaugh & Barnes, 2023). Their findings suggest the 2°C warming threshold could be reached sooner than anticipated.

Reassessing Tipping Point Timing.

University of Exeter researchers, discussed by Adam Vaughan, re-evaluated 15 major tipping points (Vaugham, 2022). Their study concluded that six could occur sooner than previously thought if global temperatures reach 3°C above pre-industrial levels, with some even possible at lower temperatures (Dockrill, 2019).

Rapidly Triggering Processes.

Fred Pearce, in Yale Environment 360, highlights the opinions of seven climate scientists (Fred Pearce, 2019). They warn that several tipping point processes could trigger more rapidly than anticipated, potentially occurring before IPCC projections. The difficulty in quantifying these points remains a point of criticism for some.

Current Status of Key Tipping Points.

Renne Cho's article, "How Close Are We to Climate Tipping Points?", outlines the current state of seven key tipping points: the Greenland and West Antarctic ice sheets, the Atlantic Meridional Overturning Circulation, the Amazon Rainforest, permafrost, and the El Niño/La Niña phenomenon, along with their potential interactions (Renne Cho, 2021).

Polar Ice Sheets.

Utilizing a new, state-of-the-art climate model, scientists from Pusan National University predict an accelerated melting of both polar ice sheets, pushing a major tipping point closer than expected (Koumoundouros, 2023). Rounce et al. predicts a global glacier melt faster than previous projections (Rounce et al., 2023).

IPCC Underestimates Complexity.

A leaked IPCC draft report, discussed by Simon Lewis and others, acknowledged the complexity and under-reporting of tipping points in past assessments (Harvey, 2021). This underestimation arose from earlier projections placing Earth-altering climate change beyond 2100.

IPCC Climate Predictions: Underestimated or Overcautious?

The Intergovernmental Panel on Climate Change (IPCC)has been a critical voice in understanding and communicating the risks of climate change. However, its climate projections have faced scrutiny for being too conservative, particularly in light of recent rapid changes. This paper explores various criticisms and potential explanations behind the perceived underestimation.

Conservative Projections and Criticisms.

The criticisms surrounding the IPCC's stance began gaining momentum after the release of its Fourth Assessment Report in 2007. Key arguments include:

Diversification of climate science.

The growing abundance of research leads to more diverse and nuanced understanding of climate change, potentially exceeding the scope captured by IPCC reports.

Underestimating specific phenomena.

James Hansen, a prominent climate scientist, argues that IPCC projections have consistently underpredicted phenomena like sea level rise, rainfall patterns, ocean heat content, Arctic ice melt, and hurricane intensity and frequency (Doyle Rice, 2023).

Systematic bias.

Brysse et al. suggest a systematic bias in IPCC projections, citing a combination of political pressures, scientific restraint to avoid alarmism, and oversimplification of information (Brysse et al., 2013). Brysse et al. also argue that the IPCC's commitment to scientific caution restricts their exploration of worst-case scenarios, potentially leading to underestimation of potential impacts. Neglecting more accurate models, some mathematical models, arguably more accurate than IPCC models, were not adequately considered, potentially contributing to underestimations. Nonlinearity of climate systems described by Edward Lorenz, the founder of chaos theory, emphasized the inherent unpredictability of atmospheric phenomena due to their nonlinearity, further challenging the feasibility of precise predictions (Steward, 2019).

Supporting Evidence.

Several studies have lent credence to the "sooner-than-predicted" concerns. Randstaf et al. underestimation of sea level rise due to underestimating Antarctic ice loss

(Rahmstorf, 2007); Pielke, has similar findings to Randstf et al.(Pielke, 2008). NRC concluded that IPCC projections were generally underestimated (Committee On Strategic Advice, 2009, p. 12). Allison et al.,observed climate change happening faster than projected (Allison et al., 2009); and Kollibri Terre Sonnenblume compiled evidence from various sources supporting the "sooner-than-predicted" argument (Kollibri Sonnenblume, 2019). Kopp et al. recommend that, because Antarctic melting projections were designed with great uncertainty models, projections should take extreme sea level rise scenarios into account for the actual faster ice mass loss than in existing models(Kopp et al., 2017).

Moving Forward:

The debate surrounding IPCC projections highlights the inherent complexities and uncertainties in climate change science. While striving for scientific rigor is essential, it's crucial to acknowledge and address potential biases and limitations in predictive models. Balancing caution with transparently communicating the full range of potential risks, including worst-case scenarios, is critical for informing effective climate action (Paul Voosen, 2021).

To Take in Consideration / Analyze/ and To Think About

Albedo

Sunlight's journey to Earth is a dynamic interplay of reflection and absorption.

As solar light reaches the atmosphere (Villanueva, 2010)), it encounters a filter of clouds and different gasses bouncing back before a portion finally touches the surface

(U.S. Department of Energy, 2024a). Among this spectrum are ultraviolet (UV) and infrared (IR) light, also reflected back to space by Earth's surface. This phenomenon of light reflection is called albedo.

It was this principle of albedo that Karl Sagan (Carl Sagan, 1985)and James Hansen (Shabecoff, 1988) relied on during their historic Congressional Hearings outlining the potential for greenhouse gasses like CO2 and GHGs to trap some of this reflected energy, leading to global warming. In 2007, Hansen further emphasized the critical threshold of 350 ppm CO2 for atmospheric stability, and in 2023, he reiterated the concerns surrounding elevated CO2 concentrations and their greenhouse effect (J. Hansen et al., 2023).

While the greenhouse effect is well-established (Columbia Climate School, 2021), there's room for nuanced understanding. Here are some points to consider:

1. Thermodynamics Energy and Oxidation: Researchers often focus on CO2 optical-spectrum alone, neglecting the energetic implications of CO, a product of fossil fuel combustion. The oxidation of carbon to CO and CO2 releases energy – an exothermic reaction governed by thermodynamics (Carbon Monoxide Gas - CO - Specific Heat vs. Temperature, n.d.).

2. Thermodynamics and Heating: Once liberated, this energy naturally heats the environment, consistent with thermodinamico laws (Gable, 2020). Yet, the connection between the greenhouse effect and these fundamental laws remains unexamined.

3. Passive Heat Release: Unlike machinery that utilizes almost all energy for various purposes, fossil fuel combustion often releases heat directly into the environment (Fuels - Higher and Lower Calorific Values, 2024). Think of warming your home with oil in winter: this heat loss parallels numerous industrial processes contributing directly to Earth's rising temperature.

4.Solar Umbrella Filtering and Trapping: If, as the greenhouse effect suggests, GHGs trap UV and IR light, shouldn’t they also filter them before reaching the surface, ¿similar to clouds? This raises questions about whether these gasses could act more like umbrellas, potentially mitigating the overall amount of UV and IR reaching the surface.

5. Farming Greenhouse

Stemmed from curiosity about agricultural greenhouse management. The first reading I encountered provided a surprising hint: greenhouse management emphasizes the importance of heating (Mortensen, 1987). While this seemed to contradict the fundamentals of global warming theory, it resonated with a spectral analysis of CO2 arguing its spectral limitation to absorb infrared radiation reflected by Earth back to space. Further research, including several papers on greenhouse management, confirmed this initial discovery (Ghiat et al., 2021, 2021; Wang et al., 2022). Badji et al. describe the complex interplay of factors like humidity, water, temperature, light, and CO2, outlining various sophisticated methodologies employed by farmers (Badji et al., 2022).

Notably, greenhouse farming manuals consistently affirm the challenge and complexity of heating greenhouses from 17 to 20-22°C (Chen et al., 2022). Surprisingly, sunlight alone cannot maintain a warm enough environment for plant growth, leading to the common practice of using natural gas for heating. The only instance of cooling mentioned was in a desert greenhouse. Mario and Maria's research offers a valuable literature review of greenhouse management, highlighting the essential role of natural gas or other resources in heating greenhouse environments.

Farming Greenhouse Limited Experimental Evidence: While numerous observations and climate models support the greenhouse effect, definitive experiments directly linking CO2 levels to increased greenhouse temperatures are nonexistent. Conversely, greenhouse farming applies CO2 to promote plant's growth until 2000 ppm and to keep 20-22° C temperature uses artificial heating mainly burning natural gas (Bruce Dunn & Megha Poudel, 2023). It could show sunlight and a high concentration of CO2 concentration do not increase greenhouse temperature. Consider a car parked under the sun: it gets hot even without CO2 present, highlighting the inherent heating capacity of sunlight.

Needs of more research: these points invite further exploration into the multifaceted relationship between albedo, greenhouse gasses, and Earth's energy balance. A deeper understanding of these interactions will be crucial in formulating effective strategies to address the challenges of climate change.

Physical-Optical Limitations

Analyzing the optical impact of CO2 and GHG on climate change.

The claim that carbon dioxide (CO2) and greenhouse gasses (GHG) trap ultraviolet (UV) and infrared (IR) light contributing to global warming, has generated fervent debate. Proponents cite their optical behavior and absorption properties, while critics question the efficiency and overall impact of such interactions (Pierre Gosselin, 2023). Let's delve into the science, examining the optical limitations of CO2 and GHGs in trapping these energies.

Optical Properties and Limitations:

Light, including UV and IR, indeed exhibits reflection, refraction (Bideau-Mehu et al., 1973; He et al., 2021; Marchetti & Simili, 2006), scattering and diffraction (*3.3*, 2022), dispersion, and other well-established behaviors upon encountering the atmosphere. However, the key aspect under scrutiny is absorption, crucial for trapping energy and influencing temperature because CO2 absorbs less UV at lower temperatures (Venot et al., 2018).
Here's the crux: the concentration of CO2 and GHG in the atmosphere, around 400 ppm (parts per million), is incredibly low (Frank Reinhart, 2017). 300-500 ppm is the normal CO2 concentration outdoors (ID Number: (ashrae.org) compared with classrooms that can reach 5000 ppm (*High CO2 Levels Indoors Will Surprise You*, 2023). Compared to ozone and water vapor, major atmospheric absorbers, CO2's capacity for UV and IR is significantly lower.

CO2 Experimental Observations:

Scientific experiments, while often conducted under higher concentrations for practical reasons, also point towards limitations. While CO2 absorbs some IR radiation at

specific wavelengths (around 4.3 and 15-micron), its effect pales in comparison to water vapor and ozone, which absorb across several frequencies and more efficiently. In addition, most of the earth's irradiation is about 16-micron (W. J. Witteman, 2020).

Furthermore, some argue that increased CO2, instead of trapping outgoing IR radiation from Earth, should result in less absorption of incoming solar IR, potentially leading to cooling. This raises important questions about the overall net effect of CO2 and GHGs. Certainly, the effect of atmospheric aerosols was researched by Li et al. and concluded that these will cool the surface (Z. Li et al., 2017).

Unresolved Questions and the Need for Nuance:

The debate surrounding CO2 and GHG necessitates a nuanced understanding. While their optical limitations in terms of absorption and concentration deserve consideration, several factors complicate the picture (Charles Anderson, 2013):

- Combined effects: The synergistic impact of various gasses and their interactions need to be considered. While individual interactions might seem weak, their combined effect could be significant.
- Feedback loops: Increased temperatures can trigger further emissions and changes in atmospheric composition, creating complex feedback loops that amplify or dampen warming effects.
- Long-term trends: Observed trends in global temperatures over decades, despite fluctuations, point towards a warming planet. While attributing this solely to CO2 and GHGs requires careful analysis (“Global Satellite Temperature vs. Atmospheric CO2 Concentration,” 2021).

IR Absorption Frequency:

CO2 primarily absorbs IR radiation at specific wavelengths, notably at 4.2 microns. However, water vapor absorbs more broadly across the IR spectrum (Pierrehumbert, 2011, p. 237; Watts, 2012). This effect is crucial for trapping outgoing heat from Earth, water vapor becoming the most important contributor to global warming(Jet Propulsion Laboratory NASA, 2019) .

Ozone's Role:

More ozone filters more UV solar, thus, reaches less energy the surface? With more CO2, do less solar UV and IR reach the surface? (Chung Chieg, 2015).

CO2 Role of reducing the incoming UV and IR reaching Surface:

The role of ozone is filtering and scattering solar light, UV, and IR reducing the incoming UV and IR reaching surface. More ozone filters more UV solar, thus, less energy reaches the surface. Conversely, with more CO2, do less solar UV and IR reach the surface? (Chung Chieg, 2015).

Water Vapor vs. CO2:

While water vapor is a more potent greenhouse gas due to its broader IR absorption spectrum (Hale & Querry, 1973), what is the role of this interplay in the Earth's energy balance? The role of water vapor trapping heat UV and IR absorption is much more important and prevalent than CO2.

The wavelength of photons that can heat the earth is less than 10.04-microns, but CO2 mainly absorbs-15 microns, thus the CO2 molecules absorb radiation that can not heat the Earth ("CO2 Infrared Absorption," 2021). Water vapor becomes tiny ice crystals at low temperatures existent at an elevation of 31-53 miles (50-85 km) above the Earth's surface. However, ice begins to form from 1.3 miles (2 km) above the Earth's surface (Gaby Pilson, 2023).

Water Vapor and CO2: Acid Carbonic:

Athmospheric carbonic acid (H_2CO_3) is produced when carbon dioxide (CO_2) dissolves in water through a hydrolysis reaction. However, it typically doesn't exist as a free molecule for long. Almost immediately, carbonic acid dissociates, breaking down into bicarbonate (HCO_3^-) and hydrogen (H^+) ions, which become dissolved components in the solution. While carbonic acid forms naturally, its existence in an aqueous environment typically lasts only 300 nanoseconds (lcyarris, 2014). This makes it a very elusive reaction, requiring sophisticated experimental and theoretical techniques for study.

One interesting property of carbonic acid is its autocatalysis ability, explained by Loerthin et al. (On the

Surprising Kinetic Stability of Carbonic Acid (H_2CO_3), wiley.com). This phenomenon accelerates the dissociation process, making carbonic acid even more unstable in the presence of water. However, it is surprisingly stable as a pure solid (anhydrous carbonic acid) at freezing temperatures. The reaction between CO_2 and water also produces hydrated CO_2 (CO_2*H_2O), and this reaction proceeds approximately 3,000 times faster than the theoric formation of carbonic acid. Analyzing carbonic acid in the ice phase (a mixture of water and CO_2) is challenging due to complex spectral changes involving hydrogen bonds. This complicates the detection of carbonic acid in atmospheric and outer space environments. Despite its fleeting existence in solution, CO_2 absorption by atmospheric and ocean water it remains crucial for the equilibrium of CO_2 between these vast reservoirs.

Cold Temperature Layer and CO2 Phase

CO2 resides in atmospheric layers with colder temperatures like the troposphere (-55°C) (weather.plus, 2024). What is the CO2 absorption capacity of UV and IR at -55 C? (*CO2 Phase Diagrams*, 2017) While CO2's role in climate change theorically is well-established, focusing solely on its atmospheric behavior misses another crucial piece of the puzzle (“Zeroth Law of Thermodynamics,” 2021). The extreme cold of the upper atmosphere significantly alters the interactions of UV and IR radiation with CO2 (Venot et al., 2018). Their behavior in these frigid conditions contrasts sharply with what we observe at ground level *(*Radiation Heat Transfer, 2024)*.*

UV and IR Properties in CO2:

What are the effects of refraction and scattering on UV and IR interactions with CO2 (*Refractive Index Common Liquids, Solids and Gases*, 2024). Ciddor research describes UV and IR refraction index in atmospheric CO2 (Ciddor, 2002)). These properties influence how radiation travels through and interacts with CO2 molecules, specially in interaction with nitrogen, ozone, and other gasses, further research in this area can be valuable (Pierrehumbert, 2011, p. 240). Voronin and Zheltitov describe air refraction and dispersion with a range from UV to long wave IR using a generalization of the Sellmeier-equation (Voronin & Zheltikov, 2017).

Ozone and UV and IR

What is the role of the ozone filtering sunlight: UV and IR ionizing oxygen to produce ozone allowing a concentration of 12 ppm at 30 kms (miles) altitude (chestr libre text books) that has significant importance in filtering and scattering the heat of solar UV and IR (Chung Chieg, 2015).

15-micron Absorption Band and Temperature:

A large portion of CO2 absorption occurs at the 15-micron band; however, CO2 also absorbs some radiation within the 10-micron band, but this absorption is non-relevant. The wavelength of photons that can heat the earth is less than 10.04-microns, but CO2 mainly absorbs-15 microns, thus the CO2 molecules also absorb radiation that can not heat the earth (Climate Auditor, 2021).

UV Absorption and Temperature Dependence:

The observed decrease in UV absorption by CO2 at lower temperatures requires further investigation. While it's a complex phenomenon requiring detailed analysis, what is CO2's role in UV trapping in the upper troposphere, where temperatures could be lower than freezing point?

Atmospheric CO2 Distribution:

CO 2 is not evenly distributed into the atmospheric layers (EarthSky, 2019); its concentration varies very broadly without any known regulation because it is constantly flowing (Jet Propulsion Laboratory, NASA, 2019).

Air has a lower specific weight than CO2.

CO2 has 1.5 times more weight than air. CO2 levels at the surface do not show this relationship (Carbon Dioxide - Density and Specific Weight vs. Temperature and Pressure, n.d.). Only very polluted cities show CO2 concentrations of order that represent a certain relationship to the atmospheric concentration (EngineeringToolBox, 2024).

In sum, these questions highlight considerations about complexities of CO2-atmospheric interactions and point to the

need for more research. Charles Anderson explains the physics leading to doubt about GHG theory (Charles Anderson, 2015)

Conclusion

The proposed change of paradigm about the cause of global warming applying thermodynamic laws will lead to a change of strategies to mitigate and solve global warming. A change of paradigm will promote broad discussions about why many predictions have been failing and how human activities should change to stop climate change.

While some arguments require further investigation and nuanced context, dismissing CO2's influence in global warming entirely would be scientifically inaccurate. Valuable considerations about the complexities of CO2-atmospheric interactions and the need for further research. A comprehensive understanding of all contributing factors, including CO2's role alongside other greenhouse gasses within the scope of the thermodynamic principles, is crucial for addressing the multifaceted challenge of climate change

This proposal considers that GHG and water vapor seal the atmosphere and avoid heat produced by inefficient energetic systems, freely released, to escape. Waste heat transmites the residual energy to the oceans and cryosphere according to thermodynamic laws.

The scientific discussion surrounding CO2, GHGs, and climate change is ongoing and multifaceted. Acknowledging the optical limitations of these gasses is crucial, but it's only one piece of the puzzle. Continued research, consideration of all contributing factors, and a commitment to evidence-based understanding is essential in navigating this complex issue.

ANEXOS

Thermodynamic Laws

The thermodynamic laws properties describe energy properties and are applicable to heating, these are four laws including Zeroth. The properties related to global warming and climate change states that:

First Law of Thermodynamics

The firt law states that the total energy of an isolated system is constant. Energy can be transformed from one form to another, but can neither be created nor destroyed (“First Law of Thermodynamics,” 2021).

Kelvin-Planck Statement about the Second Law of Thermodynamics

It’s difficult to turn all of the heat emitted by a heated body into work. No engine can transform all of the heat from the source into work without wasting any heat (“Second Law of Thermodynamics,” 2021)

Zeroth Law of Thermodynamics

The Zeroth law states that when two bodies are in thermal equilibrium with another third body then the two bodies are also in thermal equilibrium with each other (“Zeroth Law of Thermodynamics,” 2021)

Thus, human activity wastes lots of energy that is discharged to the earth as heat, absorbed by atmosphere and seawater because this heat is not used in any process and does not suffer any transformation. By following the thermodynamic laws, the energy that does not participate in any process remains in its original state, in this case the unused heat, residual energy, always remains producing global warming.

The Atmosphere

Earth's Protective Blanket: Unveiling the Layers of the Atmosphere
The atmosphere, like a protective shield, guards our planet from the harsh environment of space and nurtures life by maintaining warmth and filtering sunlight. Divided into distinct layers, each has a unique role in creating the conditions that sustain us.

Layers and Their Characteristics:

- Troposphere:

Reaching up to 8-14.5 kilometers (5-9 miles), the troposphere is the closest layer to Earth's surface, where weather phenomena like clouds, rain, and storms occur. Its temperature steadily drops with altitude, from an average of 15°C (59°F) at sea level to about -55°C (-67°F) at its upper boundary.
https://scied.ucar.edu/learning-zone/atmosphere/troposphere

- Stratosphere:

Extending to 50 kilometers (31 miles), the stratosphere is home to the protective ozone layer that absorbs harmful ultraviolet (UV) radiation from the sun. Its temperature also varies, ranging from -80°C (-112°F) over the tropics to -50°C (-58°F) in polar regions.
https://atmosphere.copernicus.eu/ozone-layer-and-ultra-violet-radiation

- Mesosphere:

Reaching up to 85 kilometers (53 miles), the mesosphere experiences the coldest temperatures in Earth's atmosphere, averaging around -90°C (-130°F). This layer is also where most meteors burn up upon entering the atmosphere.
https://spaceplace.nasa.gov/mesosphere/en/

- Thermosphere

Extending to a staggering 600 kilometers (373 miles), the thermosphere experiences extreme temperature fluctuations. With minimal air molecules, it can reach scorching highs of 2,000°C (3,632°F) during the day due to intense solar radiation, but plummet to -157°C (-250°F) at night.
https://www.vedantu.com/question-answer/which-layer-of-atmosphere-is-responsible-for-class-11-social-science-cbse-614c92c2ac388209cf04313c

- Ionosphere

Overlapping with the mesosphere and troposphere, the ionosphere stretches from 60 kilometers (30 miles) to 800 kilometers (600 miles). Here, solar radiation ionizes atmospheric gasses, creating charged particles that influence radio waves and contribute to auroras.
https://owlcation.com/stem/The-Ionosphere

- Exosphere

The outermost layer, the exosphere reaches up to 10,000 kilometers (6,200 miles) and marks the gradual transition between Earth's atmosphere and the vacuum of space. Its temperature varies greatly depending on location and solar activity.
https://www.practically.com/web/earth-and-the-layers-of-the-atmosphere.php

Hydrosphere and cryosphere

Hydrosphere

Includes all water on earth: freshwater and oceans (earthhow, 2024). 70% of this water is from oceans and oceans Cover more than 70% of earth surface. Freshwater is part of the hydrosphere and most of the freshwater is in ice caps and glaciers. Fresh water exists underground. It is the habitat of many living species; Water is essential to life. But oceans' water is not still, it is always moving and the movement in oceans forms fast moving currents. global warming affects oceans promoting hurricanes and other climate change phenomena

Cryosphere

Cryosphere is the frozen water of the earth (Initiative (ICCI), 2023). One part of this frozen water is the water around the Arctic and Antarctic. The temperatures of the cryosphere are below 0 C almost the whole year, ice and snow on land are also part of the cryosphere. An important part of the cryosphere is ice floating around water.
The cryosphere is important to control climate cooling the warm waters of the oceans and reflecting sunlight.
Climate change is affecting the cryosphere, and the size of the cryosphere is decreasing as a consequence of global warming. The cryosphere melting also promotes ocean warming, it has serious climate consequences.

Optical Properties of Light

https://oxscience.com/light/

UV frequency 280-400 nm and it is strongly affected by ozone and clouds.

UV is divided into three regions:

- UV A, wavelength = 400 - 320 nm
- UV B, wavelength = 320 - 280 nm
- UV C, wavelength = < 280 nm

IR frequency: 780 nm – 1000

- IR-A 780 – 1.4 um
- IR B 1.4 - 3 u,
- IR C 3 um – 1 mn

TheWorldCounts was created to raise awareness of important global challenges

Why is Climate Change Important? (theworldcounts.com)

AIRS Temperature Anomaly Trends in the Lower Troposphere and Upper Stratosphere, 2002-2020

29.6 MB
video/quicktime

https://airs.jpl.nasa.gov/resources/232/airs-temperature-anomaly-trends-in-the-lower-troposphere-and-upper-stratosphere-2002-2020/

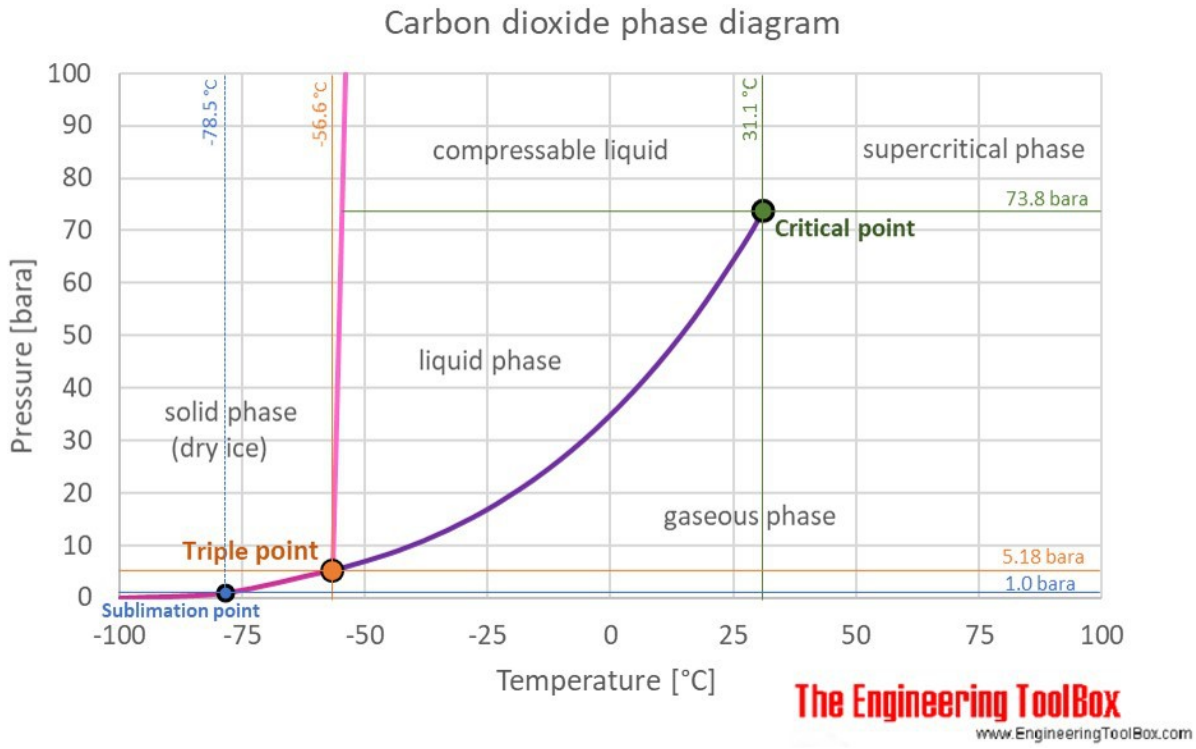
MULTIMEDIA

Visualization of multiple geophysical parameters simultaneously from AIRS data, January–April 2021

Visualization of multiple geophysical parameters simultaneously from AIRS data, January–April 2021 | AIRS (nasa.gov)

Carbon Dioxide Phase

CO2 Phase Diagrams | 101 Diagrams



In these *CO2 phase diagrams*, pressure (P) and temperature (T) are usually the coordinates. The phase diagrams usually show the (P, T) conditions for stable phases.

The phase diagram of CO_2 has some common features with that of water: sublimation curve, vaporization curve, triple point, critical temperature and pressure. Of course, the *P* and *T* values of are unique to carbon dioxide. In the following phase diagrams, shown that the triple point of carbon dioxide occure at a pressure of 5.2 atm (3952 torr) and 216.6 K (-56.4^{o}C). At temperature of 197.5 K (-78.5^{o}C), the vapor pressure of solid carbon dioxide is 1 atm (760 torr). At this pressure, the liquid phase is not stable, the solid simply sublimates. Thus, solid carbon dioxide is called dry ice, because it does not go through a liquid state in its phase transition at room pressure. The critical temperature for carbon dioxide is 31.1°C, and the critical pressure is 73 atm. Above the critical temperature, the fluid is called super-critical fluid.

The only thing special about this phase diagram is the position of the triple point which is well above atmospheric pressure. It is impossible to get any liquid carbon dioxide at pressures less than 5.11 atmospheres. That means that at 1 atmosphere pressure, carbon dioxide will sublime at a temperature of -78°C. This is the reason that solid carbon dioxide is often known as “dry ice”. You can’t get liquid carbon dioxide under normal conditions – only the solid or the vapour.

References

"1st Law of Thermodynamics." 2024. 2024. https://www.engineeringtoolbox.com/law-thermodynamics-d_93.html.

"3.3: Scattering and Diffraction." 2022. Physics LibreTexts. January 13, 2022. https://phys.libretexts.org/Bookshelves/Quantum_Mechanics/Essential_Graduate_Physics_-_Quantum_Mechanics_(Likharev)/03%3A_Higher_Dimensionality_Effects/3.03%3A_Scattering_and_Diffraction.

"2023 Is Officially Hottest Year on Record." n.d. Accessed January 20, 2024. https://interactives.ap.org/embeds/SkL6g/3/.

Adler, Robert F., Guojun Gu, Matthew Sapiano, Jian-Jian Wang, and George J. Huffman. 2017. "Global Precipitation: Means, Variations and Trends During the Satellite Era (1979–2014)." *Surveys in Geophysics* 38 (4): 679–99. https://doi.org/10.1007/s10712-017-9416-4.

Adler, Robert, Mathew Sapiano, George Huffman, Jian-Jian Wang, Guojun Gu, David Bolvin, Long Chiu, et al. 2018. "The Global Precipitation Climatology Project (GPCP) Monthly Analysis (New Version 2.3) and a Review of 2017 Global Precipitation." *Atmosphere* 9 (4): 138. https://doi.org/10.3390/atmos9040138.

Allison, Ian, Nathaniel Bindoff, Robert Bindschadler, Peter Cox, Nathalie de NOBLET, Matthew England, J.E. Francis, et al. 2009. "The Copenhagen Diagnosis," January.

Alvarez-Quintana, J. 2023. "Energy Production through Residual Heat Harvesting from Domestic/Commercial Fridges Using Nanostructured Thermoelectric Modules." *Thermal Science and Engineering Progress* 42 (July): 101952. https://doi.org/10.1016/j.tsep.2023.101952.

Argonne National Lab. 2024. "CO Enthalpy of Formation."

Ashley, Walker S., Alex M. Haberlie, and Vittorio A. Gensini. 2023. "The Future of Supercells in the United States." *Bulletin of the American Meteorological Society* 104 (1): E1–21. https://doi.org/10.1175/BAMS-D-22-0027.1.

Badji, A., A. Benseddik, H. Bensaha, A. Boukhelifa, and I. Hasrane. 2022. "Design, Technology, and Management of Greenhouse: A Review." *Journal of Cleaner Production* 373 (November): 133753. https://doi.org/10.1016/j.jclepro.2022.133753.

Ben Raker. 2024. "Researchers Are Harnessing 'Huge Problem' of Heat Waste to Power Greenhouses of the Future: 'Responsible' and 'Profitable.'" Yahoo Tech. January 17, 2024. https://www.yahoo.com/tech/researchers-harnessing-huge-problem-heat-070000872.html.

Bendig, Matthias, François Maréchal, and Daniel Favrat. 2013. "Defining 'Waste Heat' for Industrial Processes." *Applied Thermal Engineering*, 15th Conference on Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction, 61 (1): 134–42. https://doi.org/10.1016/j.applthermaleng.2013.03.020.

Bideau-Mehu, A., Y. Guern, R. Abjean, and A. Johannin-Gilles. 1973. "Interferometric Determination of the Refractive Index of Carbon Dioxide in the Ultraviolet Region." *Optics Communications* 9 (4): 432–34. https://doi.org/10.1016/0030-4018(73)90289-7.

British Atlantic Survey. 2023. “Study Provides Close-up View of Melting underneath the Thwaites Glacier.” 2023. https://phys.org/news/2023-02-close-up-view-thwaites-glacier.html.
Bruce Dunn and Megha Poudel. 2023. “Greenhouse Carbon Dioxide Supplementation - Oklahoma State University.” September 1, 2023. https://extension.okstate.edu/fact-sheets/greenhouse-carbon-dioxide-supplementation.html.
Brysse, Keynyn, Naomi Oreskes, Jessica O’Reilly, and Michael Oppenheimer. 2013. “Climate Change Prediction: Erring on the Side of Least Drama?” *Global Environmental Change* 23 (1): 327–37. https://doi.org/10.1016/j.gloenvcha.2012.10.008.
“Carbon Dioxide - Density and Specific Weight vs. Temperature and Pressure.” n.d. Accessed January 26, 2024. https://www.engineeringtoolbox.com/carbon-dioxide-density-specific-weight-temperature-pressure-d_2018.html.
“Carbon Monoxide Gas - CO - Specific Heat vs. Temperature.” n.d. Accessed January 1, 2024. https://www.engineeringtoolbox.com/carbon-monoxide-d_975.html.
Carl Sagan, dir. 1985. *Carl Sagan Testifying before Congress in 1985 on Climate Change*. https://www.youtube.com/watch?v=Wp-WiNXH6hI.
“Carnot Cycle: Definition, Efficiency, PV TS Diagram, Formula.” 2021. April 24, 2021. https://mechcontent.com/carnot-cycle/.
Carrington, Damian, and Damian Carrington Environment editor. 2019. “Global Warming of Oceans Equivalent to an Atomic Bomb per Second.” *The Guardian*, January 7, 2019, sec. Environment. https://www.theguardian.com/environment/2019/jan/07/global-warming-of-oceans-equivalent-to-an-atomic-bomb-per-second.
Caton, Jerald A. 2018. “Maximum Efficiencies for Internal Combustion Engines: Thermodynamic Limitations.” *International Journal of Engine Research* 19 (10): 1005–23. https://doi.org/10.1177/1468087417737700.
Charles Anderson. 2013. “An Objectivist Individualist: Infrared-Absorbing Gases and the Earth’s Surface Temperature.” *An Objectivist Individualist* (blog). February 18, 2013. https://objectivistindividualist.blogspot.com/2013/02/infrared-absorbing-gases-and-earths.html.
———. 2015. “An Objectivist Individualist: Why Greenhouse Gas Theory Is Wrong -- An Examination of the Theoretical Basis.” *An Objectivist Individualist* (blog). 2015. https://objectivistindividualist.blogspot.com/2015/03/why-greenhouse-gas-theory-is-wrong.html.
Chen, Wei-Han, Neil S. Mattson, and Fengqi You. 2022. “Intelligent Control and Energy Optimization in Controlled Environment Agriculture via Nonlinear Model Predictive Control of Semi-Closed Greenhouse.” *Applied Energy* 320 (August): 119334. https://doi.org/10.1016/j.apenergy.2022.119334.
Cheng, Lijing, John Abraham, Kevin E. Trenberth, John Fasullo, Tim Boyer, Michael E. Mann, Jiang Zhu, et al. 2023. “Another Year of Record Heat for the Oceans.” *Advances in Atmospheric Sciences* 40 (6): 963–74. https://doi.org/10.1007/s00376-023-2385-2.
Chung Chieg. 2015. “Ozone.” Chemistry LibreTexts. August 13, 2015. https://chem.libretexts.org/Bookshelves/Environmental_Chemistry/Supplemental_Modules_(Environmental_Chemistry)/Atmospheric_Chemistry/Ozone.

Ciddor, Philip E. 2002. “Refractive Index of Air: 3. The Roles of CO_2, H_2O, and Refractivity Virials.” *Applied Optics* 41 (12): 2292–98. https://doi.org/10.1364/AO.41.002292.
Ciracì, Enrico, Eric Rignot, Bernd Scheuchl, Valentyn Tolpekin, Michael Wollersheim, Lu An, Pietro Milillo, Jose-Luis Bueso-Bello, Paola Rizzoli, and Luigi Dini. 2023. “Melt Rates in the Kilometer-Size Grounding Zone of Petermann Glacier, Greenland, before and during a Retreat.” *Proceedings of the National Academy of Sciences* 120 (20): e2220924120. https://doi.org/10.1073/pnas.2220924120.
Climate Auditor. 2021. “CO2 Infrared Absorption.” *Climate Auditor* (blog). February 6, 2021. https://climateauditor.com/co2-infrared-absorption/.
“Climate Change Fuelled Extreme Weather in 2023; Expect More Records in 2024 – World Weather Attribution.” 2023. 2023. https://www.worldweatherattribution.org/climate-change-fuelled-extreme-weather-in-2023-expect-more-records-in-2024/.
“CO2 Calculator - Emissions from Cars.” n.d. Accessed January 1, 2024. https://www.engineeringtoolbox.com/CO2-emissions-transport-car-plane-train-bus-d_2002.html.
“CO2 Phase Diagrams.” 2017. September 4, 2017. https://www.101diagrams.com/co2-phase-diagrams/.
Cohen, Judah, Laurie Agel, Mathew Barlow, Chaim I. Garfinkel, and Ian White. 2021. “Linking Arctic Variability and Change with Extreme Winter Weather in the United States.” *Science* 373 (6559): 1116–21. https://doi.org/10.1126/science.abi9167.
Columbia Climate School. 2021. “How Exactly Does Carbon Dioxide Cause Global Warming?” *State of the Planet* (blog). February 25, 2021. https://news.climate.columbia.edu/2021/02/25/carbon-dioxide-cause-global-warming/.
“Combustion Heat.” 2024. 2024. https://www.engineeringtoolbox.com/standard-heat-of-combustion-energy-content-d_1987.html.
Committee On Strategic Advice. 2009. *Read “Restructuring Federal Climate Research to Meet the Challenges of Climate Change” at NAP.Edu*. https://doi.org/10.17226/12595.
“Conduction Heat Transfer: Definition, Equation, Types, Examples [with Pdf].” 2022. April 16, 2022. https://mechcontent.com/conduction-heat-transfer/.
“Daily Melting Ice Caps.” 2024. 2024. https://www.theworldcounts.com/challenges/global-warming/the-melting-ice-caps.
Diffenbaugh, Noah S., and Elizabeth A. Barnes. 2023. “Data-Driven Predictions of the Time Remaining until Critical Global Warming Thresholds Are Reached.” *Proceedings of the National Academy of Sciences* 120 (6): e2207183120. https://doi.org/10.1073/pnas.2207183120.
Dockrill, Peter. 2019. “Tipping Points That Could Unleash a Planetary Emergency Are Now Active, Scientists Warn.” ScienceAlert. November 28, 2019. https://www.sciencealert.com/tipping-points-unleashing-a-planetary-emergency-are-already-active-scientists-warn.
Doyle Rice. 2023. “Experts Underestimate How Fast Earth Is Warming, Top Climate Scientist Says in New Study.” USA TODAY. 2023. https://www.usatoday.com/story/news/weather/2023/11/02/global-warming-to-accelerate-faster-than-expected-james-hansen-says/71410876007/.

Dr Sam Burgess ?□□□? [@OceanTerra]. 2023. “Provisional ERA5 Global Temperature for 17th November from @CopernicusECMWF Was 1.17°C above 1991-2020 - the Warmest on Record. Our Best Estimate Is That This Was the First Day When Global Temperature Was More than 2°C above 1850-1900 (or Pre-Industrial) Levels, at 2.06°C. Https://T.Co/jXF8oRZeip.” Tweet. *Twitter*. https://twitter.com/OceanTerra/status/1726342052961493328.

Earth Observatory. 2023. “Relentless Heat in the Southwest.” Text.Article. NASA Earth Observatory. July 27, 2023. https://earthobservatory.nasa.gov/images/151632/relentless-heat-in-the-southwest.

earthhow. 2024. “The Hydrosphere: A Deep Dive into Earth’s Water.” Earth How. January 24, 2024. https://earthhow.com/hydrosphere/.

“Earth’s Atmospheric Layers - NASA.” n.d. Accessed January 3, 2024. https://www.nasa.gov/image-article/earths-atmospheric-layers-3/.

EarthSky. 2019. “6 Things to Know about Carbon Dioxide | Earth | EarthSky.” July 2, 2019. https://earthsky.org/earth/6-things-to-know-carbon-dioxide-co2-greenhouse-gas/.

Emma Rubin. 2023. “How Sea Levels in 40 Cities Will Change by 2050.” Stacker. 2023. https://stacker.com/environment/how-sea-levels-40-cities-will-change-2050.

Energy Education. 2024. “Waste Heat - Energy Education.” 2024. https://energyeducation.ca/encyclopedia/Waste_heat.

energy-efficiency-centre-of-excellence-ebook. 2021. “Energy-Efficiency-Centre-of-Excellence-Ebook.” Equinix. https://cloud.kapostcontent.net/pub/1da4c04a-a663-415d-83e0-f6f924eb0415/energy-efficiency-centre-of-excellence-ebook?kui=FUC6XGTEFcnD31U4lkpgnw.

Engineering ToolBox. 2024. “Fossil vs. Alternative Fuels - Energy Content.” 2024. https://www.engineeringtoolbox.com/fossil-fuels-energy-content-d_1298.html.

EngineeringToolBox. 2024a. “Carbon Dioxide - Thermophysical Properties.” 2024. https://www.engineeringtoolbox.com/CO2-carbon-dioxide-properties-d_2017.html.

engineeringtoolbox. 2024. “Electrical Motors - Heat Loss.” 2024. https://www.engineeringtoolbox.com/electrical-motor-heat-loss-d_898.html.

EngineeringToolBox. 2024b. “Energy Content in Common Energy Sources.” 2024. https://www.engineeringtoolbox.com/energy-content-d_868.html.

EU Copernicus. 2023. “OBSERVER: EU Copernicus Ocean State Report Highlights a Continuously Changing Ocean | Copernicus.” 2023. https://www.copernicus.eu/es/node/38063.

“Extreme Heat in North America, Europe and China in July 2023 Made Much More Likely by Climate Change – World Weather Attribution.” 2023. 2023. https://www.worldweatherattribution.org/extreme-heat-in-north-america-europe-and-china-in-july-2023-made-much-more-likely-by-climate-change/.

“Extreme Weather | WESR - Climate Change.” n.d. Accessed January 20, 2024. https://data.unep.org/climate/impacts/extreme-weather.

“First Law of Thermodynamics.” 2021. *GeeksforGeeks* (blog). July 1, 2021. https://www.geeksforgeeks.org/first-law-of-thermodynamics/.

Frank Reinhart. 2017. “Swiss Physicist Concludes IPCC Assumptions ‘Violate Reality’… CO2 A ‘Very Weak Greenhouse Gas.’” 2017. https://notrickszone.com/2017/07/17/swiss-physicist-concludes-ipcc-assumptions-violate-reality-co2-a-very-weak-greenhouse-gas/.
Fred Pearce. 2019. “As Climate Change Worsens, A Cascade of Tipping Points Looms.” Yale E360. 2019. https://e360.yale.edu/features/as-climate-changes-worsens-a-cascade-of-tipping-points-looms.
Frey, Chris. 2017. “Schweizer Physiker: IPCC-Hypothesen ‚vergewaltigen die Realität‘ … CO2 nur ein ‚sehr schwaches Treibhausgas‘.” July 23, 2017. https://eike-klima-energie.eu/2017/07/23/schweizer-physiker-ipcc-hypothesen-vergewaltigen-die-realitaet-co2-nur-ein-sehr-schwaches-treibhausgas/.
“Fuels - Higher and Lower Calorific Values.” 2024. 2024. https://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html.
Gaby Pilson. 2023. “Identifying The 10 Types of Clouds: Pictures & Chart (+ 14 Seldom Ones).” April 6, 2023. https://outforia.com/types-of-clouds/.
Gensini, Vittorio A., and Harold E. Brooks. 2018. “Spatial Trends in United States Tornado Frequency.” *Npj Climate and Atmospheric Science* 1 (1): 1–5. https://doi.org/10.1038/s41612-018-0048-2.
Ghiat, Ikhlas, Farhat Mahmood, Rajesh Govindan, and Tareq Al-Ansari. 2021. “CO2 Utilisation in Agricultural Greenhouses: A Novel ‘Plant to Plant’ Approach Driven by Bioenergy with Carbon Capture Systems within the Energy, Water and Food Nexus.” *Energy Conversion and Management* 228 (January): 113668. https://doi.org/10.1016/j.enconman.2020.113668.
“Global Satellite Temperature vs. Atmospheric CO2 Concentration.” 2021. *Climate Auditor* (blog). May 28, 2021. https://climateauditor.com/global-satellite-temperature-vs-atmospheric-co2-concentration/.
Gu, Guojun, and Robert F. Adler. 2023. “Observed Variability and Trends in Global Precipitation during 1979–2020.” *Climate Dynamics* 61 (1–2): 131–50. https://doi.org/10.1007/s00382-022-06567-9.
Hale, George M., and Marvin R. Querry. 1973. “Optical Constants of Water in the 200-Nm to 200-Mm Wavelength Region.” *Applied Optics* 12 (3): 555. https://doi.org/10.1364/AO.12.000555.
Hansen, James E, Makiko Sato, Leon Simons, Larissa S Nazarenko, Isabelle Sangha, Pushker Kharecha, James C Zachos, et al. 2023. “Global Warming in the Pipeline.” *Oxford Open Climate Change* 3 (1): kgad008. https://doi.org/10.1093/oxfclm/kgad008.
Hansen, James, Makiko Sato, and Reto Ruedy. 2023. “The Climate Dice Are Loaded. Now, a New Frontier?” *2023*.
harrisson, thomas. 2017. “Analysis: How Well Have Climate Models Projected Global Warming?” Carbon Brief. October 5, 2017. https://www.carbonbrief.org/analysis-how-well-have-climate-models-projected-global-warming/.
Harry Baker. 2023. “Energy of ‘25 Billion Atomic Bombs’ Trapped on Earth in Just 50 Years, All Because of Global Warming.” Livescience.Com. May 5, 2023. https://www.livescience.com/planet-earth/climate-change/energy-of-25-billion-atomic-bombs-trapped-on-earth-in-just-50-years-all-because-of-global-warming.

Harvey, Fiona. 2021. “IPCC Steps up Warning on Climate Tipping Points in Leaked Draft Report.” *The Guardian*, June 23, 2021, sec. Environment. https://www.theguardian.com/environment/2021/jun/23/climate-change-dangerous-thresholds-un-report.

He, Quanfu, Zheng Fang, Ofir Shoshanim, Steven S. Brown, and Yinon Rudich. 2021. “Scattering and Absorption Cross Sections of Atmospheric Gases in the Ultraviolet–Visible Wavelength Range (307–725 Nm).” *Atmospheric Chemistry and Physics* 21 (19): 14927–40. https://doi.org/10.5194/acp-21-14927-2021.

Heat Rejection. 2024. “Internal Combustion Engine Stages.” 2024. https://www.grc.nasa.gov/WWW/K-12/airplane/engstage.html.

“High CO2 Levels Indoors Will Surprise You.” 2023. CO2 Meter. December 7, 2023. https://www.co2meter.com/blogs/news/high-carbon-dioxide-co2-levels-indoors.

“How Exactly Does Carbon Dioxide Cause Global Warming?” 2021. *State of the Planet* (blog). February 25, 2021. https://news.climate.columbia.edu/2021/02/25/carbon-dioxide-cause-global-warming/.

Huang, Boyin, Viva F. Banzon, Eric Freeman, Jay Lawrimore, Wei Liu, Thomas C. Peterson, Thomas M. Smith, Peter W. Thorne, Scott D. Woodruff, and Huai-Min Zhang. 2015. “Extended Reconstructed Sea Surface Temperature Version 4 (ERSST.v4). Part I: Upgrades and Intercomparisons.” *Journal of Climate* 28 (3): 911–30. https://doi.org/10.1175/JCLI-D-14-00006.1.

Huang, Boyin, Peter W. Thorne, Viva F. Banzon, Tim Boyer, Gennady Chepurin, Jay H. Lawrimore, Matthew J. Menne, Thomas M. Smith, Russell S. Vose, and Huai-Min Zhang. 2017. “Extended Reconstructed Sea Surface Temperature, Version 5 (ERSSTv5): Upgrades, Validations, and Intercomparisons.” *Journal of Climate* 30 (20): 8179–8205. https://doi.org/10.1175/JCLI-D-16-0836.1.

IEA. 2024. “Demand – Coal Market Update – July 2023 – Analysis.” IEA. 2024. https://www.iea.org/reports/coal-market-update-july-2023/demand.

İlhami. 2021. “Greenhouse Heating.” In *Greenhouse Engineering*. CRC Press.

imdad.alvi. 2023. “What Are the 7 Properties of Light for Kids Class 10?” *Ox Science* (blog). July 26, 2023. https://oxscience.com/light/.

“Industrial Heating and Residual Heat Emission.” 2024. In *Decarbonize Urban Heating System : China Building Energy and Emission Yearbook 2023*, 77–83. Singapore: Springer Nature. https://doi.org/10.1007/978-981-99-7875-5_4.

Jacobo, Julia, A. B. C. 2021. “Melting Arctic Ice Will Have Catastrophic Effects on the World, Experts Say. Here’s How.” ABC News. December 2021. https://abcnews.go.com/International/melting-arctic-ice-catastrophic-effects-world-experts/story?id=81588333.

Jet Propulsion Laboratory, NASA. 2019. “Concentration of Atmospheric Carbon Dioxide from Earth’s Mid-Troposphere, 2002 to 2013.” AIRS. 2019. https://airs.jpl.nasa.gov/resources/107/concentration-of-atmospheric-carbon-dioxide-from-earths-mid-troposphere-2002-to-2013.

Jet Propulsion Laboratory NASA. 2019. “Mean Clear Air Precipitable Water, 500mb to Top-of-Atmosphere, January and July 2003.” AIRS. 2019.

https://airs.jpl.nasa.gov/resources/212/mean-clear-air-precipitable-water-500mb-to-top-of-atmosphere-january-and-july-2003.
Jet Propulsoin Laboratory. 2024. “AIRS Temperature Anomaly Trends in the Lower Troposphere and Upper Stratosphere, 2002-2020.” AIRS. 2024. https://airs.jpl.nasa.gov/resources/232/airs-temperature-anomaly-trends-in-the-lower-troposphere-and-upper-stratosphere-2002-2020.
Kiest, Kristina. 2021. “Executive Summary.” *NOAA Arctic* (blog). October 4, 2021. https://arctic.noaa.gov/report-card/report-card-2021/executive-summary-2/.
“Kiloton of TNT to Barrel of Oil Equivalent (US).” n.d. Accessed January 1, 2024. https://www.unitsconverters.com/en/Kiloton-To-Barrelofoilequivalent(Us)/Unittounit-3486-3483.
King, Andrew, and Steven Sherwood. 2023. “Two Trillion Tonnes of Greenhouse Gases, 25 Billion Nukes of Heat: Are We Pushing Earth out of the Goldilocks Zone?” The Conversation. May 2, 2023. http://theconversation.com/two-trillion-tonnes-of-greenhouse-gases-25-billion-nukes-of-heat-are-we-pushing-earth-out-of-the-goldilocks-zone-202619.
Klare, Michael T. 2023. “We Are Witnessing the First Stages of Civilization’s Collapse,” August 22, 2023. https://www.thenation.com/article/environment/civilization-collapse-climate-change/.
Kollibri Sonnenblume. 2019. “Climate Change: Why Is It So Often ‘Sooner than Predicted’?” Resilience. June 19, 2019. https://www.resilience.org/stories/2019-06-19/climate-change-why-is-it-so-often-sooner-than-predicted/.
Kopp, Robert E., Robert M. DeConto, Daniel A. Bader, Carling C. Hay, Radley M. Horton, Scott Kulp, Michael Oppenheimer, David Pollard, and Benjamin H. Strauss. 2017. “Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections.” *Earth’s Future* 5 (12): 1217–33. https://doi.org/10.1002/2017EF000663.
Koumoundouros, Tessa. 2023. “Ice Sheet Collapse at Both Poles to Start Sooner Than Expected, Study Warns.” ScienceAlert. February 27, 2023. https://www.sciencealert.com/ice-sheet-collapse-at-both-poles-to-start-sooner-than-expected-study-warns.
———. 2024. “Scientists Discover Alarming Evidence Global Warning Is Accelerating.” ScienceAlert. January 19, 2024. https://www.sciencealert.com/scientists-discover-alarming-evidence-global-warning-is-accelerating.
“Laws of Thermodynamics, Kepler, Newton, Einstein.” n.d. Accessed January 14, 2024. https://geocities.ws/ciencia_farma/nat_laws.htm.
lcyarris. 2014. “New Insights on Carbonic Acid in Water - Berkeley Lab.” Berkeley Lab News Center. October 22, 2014. https://newscenter.lbl.gov/2014/10/22/new-insights-on-carbonic-acid-in-water/.
“Le Chatelier’s Principle.” 2024. 2024. https://chemed.chem.purdue.edu/genchem/topicreview/bp/ch16/lechat.php.
Lenton, Timothy M., Johan Rockström, Owen Gaffney, Stefan Rahmstorf, Katherine Richardson, Will Steffen, and Hans Joachim Schellnhuber. 2019. “Climate Tipping Points

— Too Risky to Bet Against." *Nature* 575 (7784): 592–95. https://doi.org/10.1038/d41586-019-03595-0.
Lenton, Timothy M., Chi Xu, Jesse F. Abrams, Ashish Ghadiali, Sina Loriani, Boris Sakschewski, Caroline Zimm, et al. 2023. "Quantifying the Human Cost of Global Warming." *Nature Sustainability* 6 (10): 1237–47. https://doi.org/10.1038/s41893-023-01132-6.
Li, Qian, Matthew H. England, Andrew McC Hogg, Stephen R. Rintoul, and Adele K. Morrison. 2023. "Abyssal Ocean Overturning Slowdown and Warming Driven by Antarctic Meltwater." *Nature* 615 (7954): 841–47. https://doi.org/10.1038/s41586-023-05762-w.
Li, Zhanqing, Jianping Guo, Aijun Ding, Hong Liao, Jianjun Liu, Yele Sun, Tijian Wang, Huiwen Xue, Hongsheng Zhang, and Bin Zhu. 2017. "Aerosol and Boundary-Layer Interactions and Impact on Air Quality." *National Science Review* 4 (6): 810–33. https://doi.org/10.1093/nsr/nwx117.
Lowry, Daniel P., Mario Krapp, Nicholas R. Golledge, and Alanna Alevropoulos-Borrill. 2021. "The Influence of Emissions Scenarios on Future Antarctic Ice Loss Is Unlikely to Emerge This Century." *Communications Earth & Environment* 2 (1): 1–14. https://doi.org/10.1038/s43247-021-00289-2.
Marchetti, S., and R. Simili. 2006. "Accurate Measurement of the Refractive Index of CO2, N2, He, O2, and Air at 10.57μ and T=23°C." *Infrared Physics & Technology* 47 (3): 263–66. https://doi.org/10.1016/j.infrared.2004.12.005.
Menne, Matthew J., Claude N. Williams, Byron E. Gleason, J. Jared Rennie, and Jay H. Lawrimore. 2018. "The Global Historical Climatology Network Monthly Temperature Dataset, Version 4." *Journal of Climate* 31 (24): 9835–54. https://doi.org/10.1175/JCLI-D-18-0094.1.
Milman, Oliver. 2023. "'Tornado Alley' Is Shifting Farther into the US East, Climate Scientists Warn." *The Guardian*, April 4, 2023, sec. World news. https://www.theguardian.com/world/2023/apr/04/us-tornadoes-global-heating-climate-science.
Mortensen, Leiv M. 1987. "Review: CO2 Enrichment in Greenhouses. Crop Responses." *Scientia Horticulturae* 33 (1): 1–25. https://doi.org/10.1016/0304-4238(87)90028-8.
NASA. 2024. "Otto Cycle Thermodynamic Analysis." 2024. https://www.grc.nasa.gov/WWW/K-12/airplane/ottoa.html.
"NASA Scientist Issues Grim Warning 35 Years after His Original Prediction: '[W]e Knew It Was Coming.'" n.d. Accessed January 20, 2024. https://www.yahoo.com/news/nasa-scientist-issues-grim-warning-190000490.html.
NASA's Jet Propulsion Laboratory. 2022. "Ocean Heat Content | NASA Global Climate Change." Climate Change: Vital Signs of the Planet. 2022. https://climate.nasa.gov/vital-signs/ocean-warming.
National Ocean Service. 2024. "What Is the AMOC?" 2024. https://oceanservice.noaa.gov/facts/amoc.html.
National Oceanic and Atmospheric Administration. 2024. "Annual 2023 Global Climate Report," 2024. https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202313.

Naughten, Kaitlin A., Paul R. Holland, and Jan De Rydt. 2023. “Unavoidable Future Increase in West Antarctic Ice-Shelf Melting over the Twenty-First Century.” *Nature Climate Change* 13 (11): 1222–28. https://doi.org/10.1038/s41558-023-01818-x.
Paul Voosen. 2021a. “The Temperatures of Outer Space Around the Earth.” Sciencing. 2021. https://sciencing.com/temperatures-outer-space-around-earth-20254.html.
———. 2021b. “U.N. Climate Panel Confronts Implausibly Hot Forecasts of Future Warming.” 2021. https://www.science.org/content/article/un-climate-panel-confronts-implausibly-hot-forecasts-future-warming.
Pettit, Erin C., Christian Wild, Karen Alley, Atsuhiro Muto, Martin Truffer, Suzanne Louise Bevan, Jeremy N. Bassis, Anna J. Crawford, Ted A. Scambos, and Doug Benn. 2021. “Collapse of Thwaites Eastern Ice Shelf by Intersecting Fractures.” In . AGU. https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/978762.
Pielke, Roger A. 2008. “Climate Predictions and Observations.” *Nature Geoscience* 1 (4): 206–206. https://doi.org/10.1038/ngeo157.
Pierre Gosselin. 2023. “160 Papers: Low Sensitivity.” 2023. https://notrickszone.com/50-papers-low-sensitivity/.
Pierrehumbert. 2011. “Infrared Radiation and Planetary Temperature | AIP Conference Proceedings | AIP Publishing.” 2011. https://pubs.aip.org/aip/acp/article-abstract/1401/1/232/847642/Infrared-Radiation-and-Planetary-Temperature?redirectedFrom=fulltext.
“Radiation Heat Transfer.” 2024. 2024. https://www.engineeringtoolbox.com/radiation-heat-transfer-d_431.html.
Rahmstorf, Stefan. 2007. “A Semi-Empirical Approach to Projecting Future Sea-Level Rise.” *Science (New York, N.Y.)* 315 (February): 368–70. https://doi.org/10.1126/science.1135456.
Rapid Ice Melting, A. B. C. 2021. “Video Greenland’s Rapid Ice Melt Contributing to Rising Sea Levels, Scientists Say.” ABC News. 2021. https://abcnews.go.com/WNT/video/greenlands-rapid-ice-melt-contributing-rising-sea-levels-81399816.
“Refractive Index Common Liquids, Solids and Gases.” 2024. 2024. https://www.engineeringtoolbox.com/refractive-index-d_1264.html.
Renne Cho. 2021. “How Close Are We to Climate Tipping Points?” *State of the Planet* (blog). November 11, 2021. https://news.climate.columbia.edu/2021/11/11/how-close-are-we-to-climate-tipping-points/.
Restructuring Federal Climate Research to Meet the Challenges of Climate Change. 2009. Washington, D.C.: National Academies Press. https://doi.org/10.17226/12595.
Ripple, William J, Christopher Wolf, Thomas M Newsome, Jillian W Gregg, Timothy M Lenton, Ignacio Palomo, Jasper A J Eikelboom, et al. 2021. “World Scientists’ Warning of a Climate Emergency 2021.” *BioScience* 71 (9): 894–98. https://doi.org/10.1093/biosci/biab079.
Rounce, David R., Regine Hock, Fabien Maussion, Romain Hugonnet, William Kochtitzky, Matthias Huss, Etienne Berthier, et al. 2023. “Global Glacier Change in the 21st Century: Every Increase in Temperature Matters.” *Science* 379 (6627): 78–83. https://doi.org/10.1126/science.abo1324.

Schuckmann, Karina von, Audrey Minière, Flora Gues, Francisco José Cuesta-Valero, Gottfried Kirchengast, Susheel Adusumilli, Fiammetta Straneo, et al. 2023. “Heat Stored in the Earth System 1960–2020: Where Does the Energy Go?” *Earth System Science Data* 15 (4): 1675–1709. https://doi.org/10.5194/essd-15-1675-2023.

“Second Law Of Thermodynamics: Definition, Statements and Equation.” 2021. *GeeksforGeeks* (blog). September 1, 2021. https://www.geeksforgeeks.org/second-law-of-thermodynamics/.

Seth Borenstein. 2024. “Earth Shattered Global Heat Record in ’23 and It’s Flirting with Warming Limit, European Agency Says.” AP News. January 9, 2024. https://apnews.com/article/climate-change-warming-heating-earth-europe-copernicus-60eb12d11b7e5f694848673bb58512d3.

Shabecoff, Philip. 1988. “Global Warming Has Begun, Expert Tells Senate.” *The New York Times*, June 24, 1988, sec. U.S. https://www.nytimes.com/1988/06/24/us/global-warming-has-begun-expert-tells-senate.html.

softusvista. 2024. “Barrel of Oil Equivalent (US) to Kiloton of TNT.” 2024. https://www.unitsconverters.com/en/Kilotonoftnt-To-Gigahertz/Unittounit-3486-3512.

Steward, Cindy. 2019. “Order in a Chaotic World: Introducing the Chaos Theory.” *The Startup* (blog). December 21, 2019. https://medium.com/swlh/order-in-a-chaotic-world-introducing-the-chaos-theory-2b3884497071.

Studio, University of Exeter Design. 2023. “Narrative Summary.” Global Tipping Points. 2023. https://global-tipping-points.org.

Teirstein, Zoya. 2021. “Is Climate Change Happening Faster than Expected?” Grist. July 23, 2021. https://grist.org/science/is-climate-change-happening-faster-than-expected-a-climate-scientist-explains/.

“Thermodynamics.” 2024. 2024. https://www.grc.nasa.gov/WWW/K-12/airplane/thermo.html.

U.S. Department of Energy. 2024a. “Solar Radiation Basics.” Energy.Gov. 2024. https://www.energy.gov/eere/solar/solar-radiation-basics.

———. 2024b. “Where the Energy Goes: Gasoline Vehicles.” 2024. https://fueleconomy.gov/feg/atv.shtml.

US EPA, OAR. 2015. “Climate Change Indicators: Greenhouse Gases.” Reports and Assessments. December 16, 2015. https://www.epa.gov/climate-indicators/greenhouse-gases.

Vaugham. 2022. “Six Climate Tipping Points Are Likely to Occur If We Breach 1.5°C Goal.” New Scientist. 2022. https://www.newscientist.com/article/2337002-six-climate-tipping-points-are-likely-to-occur-if-we-breach-1-5c-goal/.

Velicogna, I. 2009. “Increasing Rates of Ice Mass Loss from the Greenland and Antarctic Ice Sheets Revealed by GRACE.” *Geophysical Research Letters* 36 (19). https://doi.org/10.1029/2009GL040222.

Venot, O., Y. Bénilan, N. Fray, M.-C. Gazeau, F. Lefèvre, Et Es-sebbar, E. Hébrard, et al. 2018. “VUV-Absorption Cross Section of Carbon Dioxide from 150 to 800 K and Applications to Warm Exoplanetary Atmospheres.” *Astronomy & Astrophysics* 609 (January): A34. https://doi.org/10.1051/0004-6361/201731295.

Villanueva, John Carl. 2010. “Gases In The Atmosphere.” *Universe Today* (blog). January 7, 2010. https://www.universetoday.com/49849/gases-in-the-atmosphere/.
“Visualization of Multiple Geophysical Parameters Simultaneously from AIRS Data, January–April 2021.” 2022. AIRS. 2022. https://airs.jpl.nasa.gov/resources/235/visualization-of-multiple-geophysical-parameters-simultaneously-from-airs-data-januaryapril-2021.
Voronin, A., and A. Zheltikov. 2017. “The Generalized Sellmeier Equation for Air.” *Scientific Reports* 7 (August): srep46111. https://doi.org/10.1038/srep46111.
Vose, R. S., B. Huang, X. Yin, D. Arndt, D. R. Easterling, J. H. Lawrimore, M. J. Menne, A. Sanchez-Lugo, and H. M. Zhang. 2021. “Implementing Full Spatial Coverage in NOAA’s Global Temperature Analysis.” *Geophysical Research Letters* 48 (4): e2020GL090873. https://doi.org/10.1029/2020GL090873.
W. J. Witteman. 2020. “The Absorption of Thermal Emitted Infrared Radiation by CO2 | Principia Scientific Intl.” *Principia Scientific Intl. | A Science-Based Community* (blog). April 3, 2020. https://principia-scientific.com/the-absorption-of-thermal-emitted-infrared-radiation-by-co2/.
Wang, Anran, Jianrong Lv, Jiao Wang, and Kai Shi. 2022. “CO2 Enrichment in Greenhouse Production: Towards a Sustainable Approach.” *Frontiers in Plant Science* 13. https://www.frontiersin.org/articles/10.3389/fpls.2022.1029901.
Watts, Anthony. 2012. “Earth’s Entire Thermal Infrared Spectrum Observed.” Watts Up With That? June 15, 2012. https://wattsupwiththat.com/2012/06/15/earths-entire-thermal-infrared-spectrum-observed/.
weather.plus. 2024. “Temperature of the Tropopause - Weather.Plus.” 2024. https://weather.plus/tropopause-temperature.php.
Willcock, Simon, Gregory S. Cooper, John Addy, and John A. Dearing. 2023. “Earlier Collapse of Anthropocene Ecosystems Driven by Multiple Faster and Noisier Drivers.” *Nature Sustainability* 6 (11): 1331–42. https://doi.org/10.1038/s41893-023-01157-x.
World Meteorological Organization (WMO). 2023. “World Weather and Climate Extremes Archive.” World Meteorological Organization. June 21, 2023. https://wmo.int/site/world-weather-and-climate-extremes-archive.
Wu, Shuang-Ye. 2023. “2023’s Extreme Storms, Heat and Wildfires Broke Records – a Scientist Explains How Global Warming Fuels Climate Disasters.” The Conversation. December 19, 2023. http://theconversation.com/2023s-extreme-storms-heat-and-wildfires-broke-records-a-scientist-explains-how-global-warming-fuels-climate-disasters-217500.
———. 2024. “2023’s Billion-Dollar Disasters List Shattered the US Record with 28 Big Weather and Climate Disasters amid Earth’s Hottest Year on Record.” The Conversation. January 9, 2024. http://theconversation.com/2023s-billion-dollar-disasters-list-shattered-the-us-record-with-28-big-weather-and-climate-disasters-amid-earths-hottest-year-on-record-220634.
Zanna, Laure, Samar Khatiwala, Jonathan M. Gregory, Jonathan Ison, and Patrick Heimbach. 2019. “Global Reconstruction of Historical Ocean Heat Storage and Transport.” *Proceedings of the National Academy of Sciences* 116 (4): 1126–31. https://doi.org/10.1073/pnas.1808838115.

“Zeroth Law of Thermodynamics: Definition, Application & FAQs.” 2021. *GeeksforGeeks* (blog). August 1, 2021. https://www.geeksforgeeks.org/zeroth-law-of-thermodynamics/.

Additional Recommended Readings

1. World Weather Climate Extremes Map

World Weather Climate Extremes Map (wmo.int)

Lower upper stratosphere temperatures animation
(Laboratory, 2021)
multiple geophysical visualizations
(Laboratory, n.d.)

“21.5: The Spectra of Molecules- Infrared.” 2016. Chemistry LibreTexts. May 9, 2016. https://chem.libretexts.org/Bookshelves/General_Chemistry/ChemPRIME_(Moore_et_al.)/21%3A_Spectra_and_Structure_of_Atoms_and_Molecules/21.05%3A_The_Spectra_of_Molecules-_Infrared.
“21.6: The Visible and Ultraviolet Spectra of Molecules- Molecular Orbitals.” 2016. Chemistry LibreTexts. May 9, 2016. https://chem.libretexts.org/Bookshelves/General_Chemistry/ChemPRIME_(Moore_et_al.)/21%3A_Spectra_and_Structure_of_Atoms_and_Molecules/21.06%3A_The_Visible_and_Ultraviolet_Spectra_of_Molecules-_Molecular_Orbitals.
Abnurlion. 2023. “The 3 Laws of Thermodynamics.” PHYSICS CALCULATIONS. July 13, 2023. https://physicscalculations.com/the-3-laws-of-thermodynamics/.
“An Objectivist Individualist: Evaluating the Catastrophic Man-Made Global Warming Hypothesis.” n.d. *An Objectivist Individualist* (blog). Accessed January 29, 2024. https://objectivistindividualist.blogspot.com/p/false-catastrophic-man-made-global.html.
Counts, The World. n.d. “Why Is Climate Change Important?” Accessed January 30, 2024. https://www.theworldcounts.com/challenges/climate-change/global-warming.
“Electromagnetic Spectrum.” n.d. Accessed January 26, 2024. https://www.engineeringtoolbox.com/electromagnetic-spectrum-d_1929.html.
“Energy Education.” n.d. Accessed January 28, 2024. https://energyeducation.ca/encyclopedia/Main_Page.
Environment, U. N. 2023. “Emissions Gap Report 2023.” UNEP - UN Environment Programme. November 8, 2023. http://www.unep.org/resources/emissions-gap-report-2023.
Forman, Clemens, Ibrahim Kolawole Muritala, Robert Pardemann, and Bernd Meyer. 2016. “Estimating the Global Waste Heat Potential.” *Renewable and Sustainable Energy Reviews* 57 (May): 1568–79. https://doi.org/10.1016/j.rser.2015.12.192.

Hansen, James E, Makiko Sato, Leon Simons, Larissa S Nazarenko, Isabelle Sangha, Pushker Kharecha, James C Zachos, et al. 2023. “Global Warming in the Pipeline.” *Oxford Open Climate Change* 3 (1): kgad008. https://doi.org/10.1093/oxfclm/kgad008.
Initiative (ICCI), International Cryosphere Climate. 2023. “State of the Cryosphere 2023: Major New Report Confirms Just 2°C of Warming Will Trigger Irreversible Global Damage From Loss of Earth’s Ice.” Mountain Research Initiative. November 16, 2023. https://www.mountainresearchinitiative.org/news-page-all/112-global-news/3718-state-of-the-cryosphere-2023-major-new-report-confirms-just-2-c-of-warming-will-trigger-irreversible-global-damage-from-loss-of-earth-s-ice.
Laboratory, Jet Propulsion. 2021. “AIRS Temperature Anomaly Trends in the Lower Troposphere and Upper Stratosphere, 2002-2020.” AIRS. 2021. https://airs.jpl.nasa.gov/resources/232/airs-temperature-anomaly-trends-in-the-lower-troposphere-and-upper-stratosphere-2002-2020.
———. n.d.-a. “Home.” AIRS. Accessed January 28, 2024. https://airs.jpl.nasa.gov/.
———. n.d.-b. “Visualization of Multiple Geophysical Parameters Simultaneously from AIRS Data, January–April 2021.” AIRS. Accessed January 14, 2024. https://airs.jpl.nasa.gov/resources/235/visualization-of-multiple-geophysical-parameters-simultaneously-from-airs-data-januaryapril-2021.
Lenton, Timothy M., Hermann Held, Elmar Kriegler, Jim W. Hall, Wolfgang Lucht, Stefan Rahmstorf, and Hans Joachim Schellnhuber. 2008. “Tipping Elements in the Earth’s Climate System.” *Proceedings of the National Academy of Sciences* 105 (6): 1786–93. https://doi.org/10.1073/pnas.0705414105.
McSweeney, Robert. 2018. “Q&A: How Do Climate Models Work?” Carbon Brief. January 15, 2018. https://www.carbonbrief.org/qa-how-do-climate-models-work/.
Pielke Research Group. n.d. “Climate Science.” Climate Science: Roger Pielke Sr. Accessed January 22, 2024. https://pielkeclimatesci.wordpress.com/2013/07/.
Schuckmann, Karina von, Audrey Minière, Flora Gues, Francisco José Cuesta-Valero, Gottfried Kirchengast, Susheel Adusumilli, Fiammetta Straneo, et al. 2023. “Heat Stored in the Earth System 1960–2020: Where Does the Energy Go?” *Earth System Science Data* 15 (4): 1675–1709. https://doi.org/10.5194/essd-15-1675-2023.
Studio, University of Exeter Design. n.d. “Home.” Global Tipping Points. Accessed January 25, 2024. https://global-tipping-points.org.
Tandon, Ayesha. 2023. “Q&A: Climate Tipping Points Have Put Earth on ‘Disastrous Trajectory’, Says New Report.” Carbon Brief. December 6, 2023. https://www.carbonbrief.org/qa-climate-tipping-points-have-put-earth-on-disastrous-trajectory-says-new-report/.

About the autor:

Jorge Nowell-Enriquez
ESG Consultant

M.A. Liberal Studies with focus on Eco-Geopolitical Analysis
M.A. Public Administration

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